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Special Scientific Report No. 23

STUDIES ON THE PACIFIC PILCHARD OR SARDINE

(SARDINOPS CAERULEA)

4.--Influence of Temperature on the Rate of Development of Pilchard Eggs in Nature.

By

Elbert H. Ahlstrom

Chicago
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Explanatory Note

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INTRODUCTION

In the first paper of this series[1/], Sette, 1943, has stated that a major requisite in the program of pilchard research is the measurement of recruitment. This can be obtained most directly from a quantitative sampling of pilchard eggs and larvae at sea in and around the region known to be the chief spawning grounds. Determinations of the amount of spawning require the integration (over both time and space) of the quantitative samples of eggs. To accomplish this necessitates knowing as exactly as possible the age of any particular stage of development, as well as the number of days of spawning represented in each collection. Since rate of development is strongly influenced by temperature, it is necessary to know the relation between these two variables to get a precise method of determining the age of eggs in all samples.

So far it has been unfeasible to procure live spawning pilchards for artificial fertilization and propagation of eggs. Fishermen rarely catch ripe, spawning pilchards, and we have lacked facilities wherewith we could attempt to catch them. Although eggs newly spawned were collected in the plankton samples, constant temperature apparatus was not available to permit hatching experiments under controlled conditions. Hence, it has been necessary to approach the problem analytically by correlating temperature data collected in the field with the probable length of time particular stages in the samples had been developing.

The writer is indebted to Oscar Elton Sette, in charge of the South Pacific Investigations, for continuous aid and advice throughout the development of this problem, to Dr. L. A. Walford for valuable help in the preparation of the manuscript, and to Elizabeth Vaughan for assistance and suggestions in the mathematical treatment. The plankton hauls for the most part were made by the author and other members of the South Pacific Fishery Investigation staff of the Service, while the oceanographic observations, of which the temperatures-data of this paper were a part, were the responsibility of the Scripps Institution of Oceanography staff. Sorting of the plankton collections was accomplished with the assistance of employees from Works Progress Administration projects Nos. 10917 and 65 - 2 - 08 - 286.

COLLECTION OF MATERIAL

The plankton collections on which this paper is based were made during the pilchard spawning surveys of 1940 and 1941, conducted by the South Pacific Investigations of the Fish and Wildlife Service in conjunction with the Scripps Institution of Oceanography from the research

1/ Oscar Elton Sette. Studies on the Pacific Pilchard or Sardine (Sardinops caerulea). I - Structure of a Program for Pacific Pilchard (or Sardine) Research. Special Scientific Report No. 19.

vessel, E. W. Scripps. Six cruises, each covering a pattern of approximately forty stations, were made during the spring and early summer of each year. The region surveyed is the area of maximum spawning of the pilchard (Scofield, 1934). It had as its northern limit the group of islands of which Santa Cruz is the largest, and extended in the south to near the Coronados Islands; the stations ranged from near shore to about 150 miles out to sea. The region covered and the pattern of stations occupied was somewhat different during the second season, but essentially the same area was surveyed in both years.

The methods employed in the collection of plankton samples containing pilchard eggs will be treated in detail in another paper devoted to the results of the spawning surveys of the years 1940 and 1941. For the purposes of the present article, it is sufficient to state that oblique hauls were made with either a one-meter or two-meter net from approximately 75 meters deep to the surface, the hauls taking, on the average, about 24 minutes of towing time. Stations were occupied at whatever hour of the day or night they were reached. Temperatures were taken at each station at 10-meter intervals in the upper 50 meters of water and at 25-meter intervals in the next 50 meters, with reversing thermometers attached in pairs to Nansen water bottles.

DESCRIPTION OF THE PILCHARD EGG

The pilchard egg can be readily identified by the following combination of characters: a wide perivitelline space, a single oil globule, and an irregularly segmented yolk. The eggs are spherical, with the egg membrane thin, unsculptured, quite transparent, and with a bluish or purplish cast. The egg membrane is easily broken, more so than those of most planktonic eggs; in the plankton samples studied it was commonly absent from a third to a half of the eggs, probably having been broken in the net, or in fractioning or sorting the material. Fertilized eggs average about 1.70 mm. in diameter (range 1.35 - 2.05 mm.). This is of similar size to the fertilized egg of the European pilchard. The perivitelline space is wide, having nearly as great a width as the yolk mass. We have encountered no other pelagic fish egg of the size of the pilchard egg in the area investigated that are so characterized. The yellowish-brown yolk appears to be made up of a number of irregular cells, but it is composed of a large number of separate particles of yolk material closely pressed together. There is a single oil globule, 0.16 mm. in diameter.

In connection with these studies the development of the pilchard egg was separated, on the basis of readily observable morphological character, into eleven stages which are not of equal time duration. A brief description of each stage is given in the appendix (p. 9).

TIME OF SPAWNING

As there are no actual observations on the time of day pilchards spawn in nature, this could be determined only by indirect evidence. The time of day newly-spawned eggs appear in the plankton should roughly establish the time of spawning. Such newly-spawned eggs would be pre-cleavage eggs that had not had time to begin cell division, i.e., stage I (cf. appendix). The times when pre-cleavage eggs occurred in plankton samples is summarized in tables 1 and 2. According to both tables about 87 percent of pre-cleavage eggs were taken during the four-hour period, 8:00 p.m. to midnight. At that time there were practically no eggs in the early stages of cleavage. After midnight very many pilchard eggs undergoing cleavage were in the samples taken, while only an occasional egg was of precleavage stage.

Eggs of that age taken during the four-hour period before midnight are considerably smaller in diameter than are those with some embryonic development. Since the yolks are of similar size in both groups, the difference lies in the width of the perivitelline space, which is nearly wanting in pre-cleavage eggs taken during this period; such eggs averaged only 1.20 mm. in diameter (range 1.02 - 1.38 mm.). This is slightly smaller than the average size of 1.24 mm. that F. N. Clark (1934, p. 3) reported for mature pilchard eggs from ripe females. The difference in size between eggs newly-spawned and those undergoing development (average size 1.70 mm.) could result from the latter having absorbed water, swelling the perivitelline space up to the size characteristic of planktonic pilchard eggs.

A few pre-cleavage eggs were taken in the samples after midnight. The majority of these were much larger than pre-cleavage eggs taken before midnight (cf. tables 1 and 2), in fact, were about the same size as pilchard eggs in the same samples undergoing cleavage. Hence, they must have been in the water for some time, and, consequently, must either have started development very slowly or had remained unfertilized. However, a few pre-cleavage eggs taken as late as mid-day have a very narrow perivitelline space. Either these had been spawned at the normal time but did not attain the typical planktonic egg size, or they resulted from isolated instances of deposition during the day. In numbers such eggs were negligibly few.

Further support for the thesis that spawning is rhythmical, occurring during a brief, relatively fixed time each day and not sporadically, is furnished by the time distributions of eggs undergoing cleavage. Thus, eggs in early stages of cleavage were taken immediately after midnight and not during any other period of the day, while eggs in the last stages of cleavage were collected in samples around noon. This could occur only if spawning took place during a brief period each day.

The following account of the length of time of development assumes that spawning is confined to the period, 8:00 p.m. to midnight, by taking the midpoint of this period, 10:00 p.m., as the hour when development is initiated. True, using the time of fertilization rather than of spawning would be more precise, but the two processes are believed to occur close enough together to justify neglecting the time difference between them.

Table 1.--Samples in which pre-cleavage eggs were taken

(Regular survey cruises of 1940-1941)

Station No.	Time of collection[1]	Number of pre-cleavage eggs[2]	Number of stage II eggs	Number of stage III and stage IV eggs	Av. size pre-cleavage eggs
1744	20:16	41	-	-	1.21 mm.
1752	20:34	11	-	-	1.22 "
1736	21:15	12	-	-	1.19 "
2135	21:20	22	-	-	1.15 "
1751	21:48	4	-	-	-
1731	21:53	79	1	-	1.07 "
112	22:17	15	-	-	1.31 "
105	22:30	6	-	-	1.35 "
1952	23:33	4	-	-	1.20 "
2115	23:37	100[3]	-	-	1.20 "
1745	1:02	1	2	-	-
1926	2:24	1	38	-	-
1915	2:47	1	30	-	1.60 "
336	4:00	1	75	-	-
128	5:45	1	13	-	1.78 "
1714	6:47	1	433	-	-
2325	6.58	1	156	-	1.05 "
1743	7:49	4	808	-	1:04; 1.70 mm.[4]
411	8:05	1	46	-	-
414	8:27	1	307	-	-
1955	8:35	3	225	-	-
405	9:30	1	14	-	1.60 mm.
1946	10:32	2	5	-	1.54 "
2324	10:36	3	19	-	-
1715	10:53	1	14	2	-
114	11:00	2	7	1522	-
132	11:15	1	-	60	1.65 "
1742	12:10	1	1	80	-
2113	12:27	8	523	196	-
409	12:45	1	103	1	-
2163	12:47	1	-	193	1.04 "
330	13:03	2	116	15	-
124	15:17	1	-	67	-
1726	17:25	1	-	18	-

[1] The time of collection as used in tables 1 and 2 refers to the time when the plankton net was going through the 20-10 M. zone.

[2] Number of eggs in the sorted portions of all nets used at a station, whether of 2 M, 1 M, or 1/2 M diameter.

[3] Approximate number.

[4] Eggs of two size groups.

Table 2.--Pre-cleavage eggs in samples of transection[1/]

Station No.	Time of collection	Number of pre-cleavage eggs	Number of stage II eggs	Number of stage III eggs	Average size pre-cleavage eggs
1876	19:00	-	-	-	-
1877	20:06	26	-	-	1.07 mm.
1878	21:06	112	-	-	1.13 "
1879	22:08	91	2	-	1.28 "
1880	23:11	68	12	-	1.32 "
1881	00:13	3	57	-	-
1882	1:12	5	330	-	-
1883	2:23	4	1198	-	-
1884	3:27	5	1088	-	-
1885	4:34	9	2157	-	1.68 "
1886	5:22	10	2347	-	-
1887	6:30	2	1136	195	-
1888	7:30	2	156	806	-

[1/] This table is based on collections from a special series of stations occupied on the night of April 8-9, 1941, when stations were taken on a line extending from off the southern end of San Clemente Island toward the mainland at 2.5- to 5.0-mile intervals, with about an hour's time elapsing between successive samples. Fortunately, this series of samples was obtained from a region where heavy spawning was taking place the night of collection.

DURATION OF DEVELOPMENT

The length of time required by pilchard eggs to develop to the hatching stage after being spawned and fertilized was roughly determined by placing pilchard eggs taken in plankton samples into hatching jars aboard the vessel while at sea and following their development. This was done during several cruises in 1940. In some samples the development of eggs was followed from the blastodermal cap stage to hatching. From these experiments, it was concluded that the pilchard egg ordinarily required about three days to develop to the hatching stage from the time of spawning. Because the temperature of the hatching-jars could not be kept constant with the facilities available at sea, it fluctuated several degrees during each twenty-four hour period. Hence, the data derived from these experiments is not of direct use in the study of the influence of temperature on the rate of development.

Since the pilchard egg is spawned only during a few hours of the twenty-four (8:00 p.m. to midnight), and since it requires several days for the process of development, a plankton sample should contain eggs in various stages of development; furthermore, there should be a sharp separation of the stages among eggs derived from each day's spawning. A tabulation of the stages of development present in the samples (table 6) reveals that a sample typically contains stages in various degrees of development separated by gaps of one or two stages, which are taken to represent the time gaps between successive spawnings. Thus, we have a basis for separating the stages present in a sample into their respective days of spawning[2/]; with the least advanced stage (or stages) taken to represent the most recent spawning, and so on. In some samples one or more days of spawning may not be represented, but this can usually be ascertained by a comparison with other samples. As a consequence, there are often insufficient landmarks to indicate the age of such stages as are present.

Having effected a separation of the eggs in a plankton sample into their respective days of spawning, the actual time of development of each stage present in a sample can be determined. The midpoint of spawning, 10:00 p.m., is taken as the hour when development commenced. The time of preservation of each plankton sample marks the endpoint of development of the eggs present in the sample, and this time was recorded as a part of the routine observations during collection of the material. From these data it is possible to derive the probable length of time, in hours, that each of the several stages in most samples had been developing.

WATER TEMPERATURES

In correlating the development of pilchard eggs with the temperature of the water at the station of collection, it is necessary to express the

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2/ Separation into days is indicated for each sample listed in table 6.

temperature at each station by a single value. For that purpose the average of the temperatures at 10 and 20 meters was used.[3/] This choice was based on the results of a series of horizontal hauls made with closing nets (cf. Silliman, 1943), which showed that although a few pilchard eggs are occasionally found deeper than 50 meters, nearly all occur above 30 meters, and by far the greatest concentration is usually between 10 and 20 meters or even nearer to the surface. Surface temperatures, however, were not included in the average, because of their rather marked fluctuations.

To be sure, the temperature readings may not represent exactly the average temperature to which the eggs had been subjected from spawning to the time of collection. However, we can assume, relatively safely, that the temperature of the sea water usually had not changed very much during this period of time, which, on the average, would have been only about a day and a half.

Pilchard eggs were found developing at temperatures ranging from 12.5° C. to 17.6° C. as measured by the mean of the 10 - 20 meter levels; this is an over-all range of slightly more than 5.0° C. However, the majority of samples containing pilchard eggs were taken at temperatures between 13.5° C. and 16.0° C., or within a range of 2.5° C.

INFLUENCE OF TEMPERATURE ON RATE OF DEVELOPMENT OF PILCHARD EGGS

The primary information upon which the analysis of the relation between temperature and rate of development of pilchard eggs in nature can be made are the following: (1) The estimated age, in hours, of most pilchard eggs from the time of spawning to the time of collection and (2) the temperature of the water at the depths where the majority of eggs were developing, taken at the time of collection of the eggs.

An analysis could not be made of the influence of temperature on the length of time required by the pilchard egg to develop completely to hatching, because of the difficulty of determining, from the preserved material, when hatching would have occurred. However, a correlation was possible between temperature and length of time of development of the pilchard egg to the stage immediately preceding hatching (stage XI, cf. appendix).

Not all records of stage XI could be used in the correlation, since, in some samples, only a small percentage of the eggs referred to a common day of spawning had reached this stage, the majority still being in the preceding stage; also, in a few samples the age of the eggs could not be determined with certainty. Therefore, the following criteria were set

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3/ Temperatures at 10 and 20 meters were usually closely similar, and both depth usually occurred in the stratum above the thermocline. For more than 50 percent of the items used in the subsequent correlations, the difference in temperature between these two depths was less than 0.1° C., and for only one-sixth of the items was the difference greater than 0.5° C.

up to select the records of stage XI to be used in the analysis: (1) At least four-fifths of the pilchard eggs of a given day's spawning must have reached the stage, (2) there must be at least two specimens of the stage in each included record, and (3) there must be a reasonable certainty about the length of time of development, based on evidence of associated stages of development.4/

When the length of time of development of each record of stage XI meeting the criteria was plotted as the dependent variable against the temperature of the water at the station of collection, a scatter of points was obtained that apparently could be fitted best by a curved line. By using the logarithm of the time of development for plotting against the temperature of the water a straight line distribution resulted (uppermost curve in figure 1), which was subsequently fitted by the method of least squares.

A similar correlation of temperature with length of time of development was also made on three earlier stages of pilchard eggs, III, VI, VIII-IX (combined to give more items).5/ The fitted lines for these stages, also shown in figure 1, have about the same slope as the fitted line for stage XI. In fact, when tested statistically, the four lines were not significantly different from each other ($P > .05$). The slopes are defined by the b values in the equation $Y = a+bX$; these values are listed in table 3, together with other pertinent data concerning the correlations. There is no evidence that the relation between temperature and rate of development changed during incubation. Furthermore, the results obtained for the four stages are so consistent that they justify confidence in the reliability of the method of analysis. The time (in hours after spawning) to reach each of the four stages at temperatures between 13.5 and 17.0° C. is given by 0.5 degree intervals in table 4. Within the temperature range investigated, the time to reach a stage of development is increased by about 7.15 percent for each 0.5° C. decrease in temperature. The total time of development to hatching, could be approximated by adding two to three hours time to the values listed for stage XI at the higher temperatures, and proportionately more as the temperature decreases.

Although consistent results are obtained for the several stages, there is a considerable spread of points about each line. The factors causing this variability may be associated with either the time of development or with the temperature. Variable elements associated with time undoubtedly account for most of the spread about the four fitted

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4/ The records of stage XI meeting the above criteria are indicated in table 6 by an asterisk.

5/ All records of these stages that could meet the three criteria previously described for stage XI were used in the correlations; these are indicated in table 6 by an asterisk.

FIGURE 1

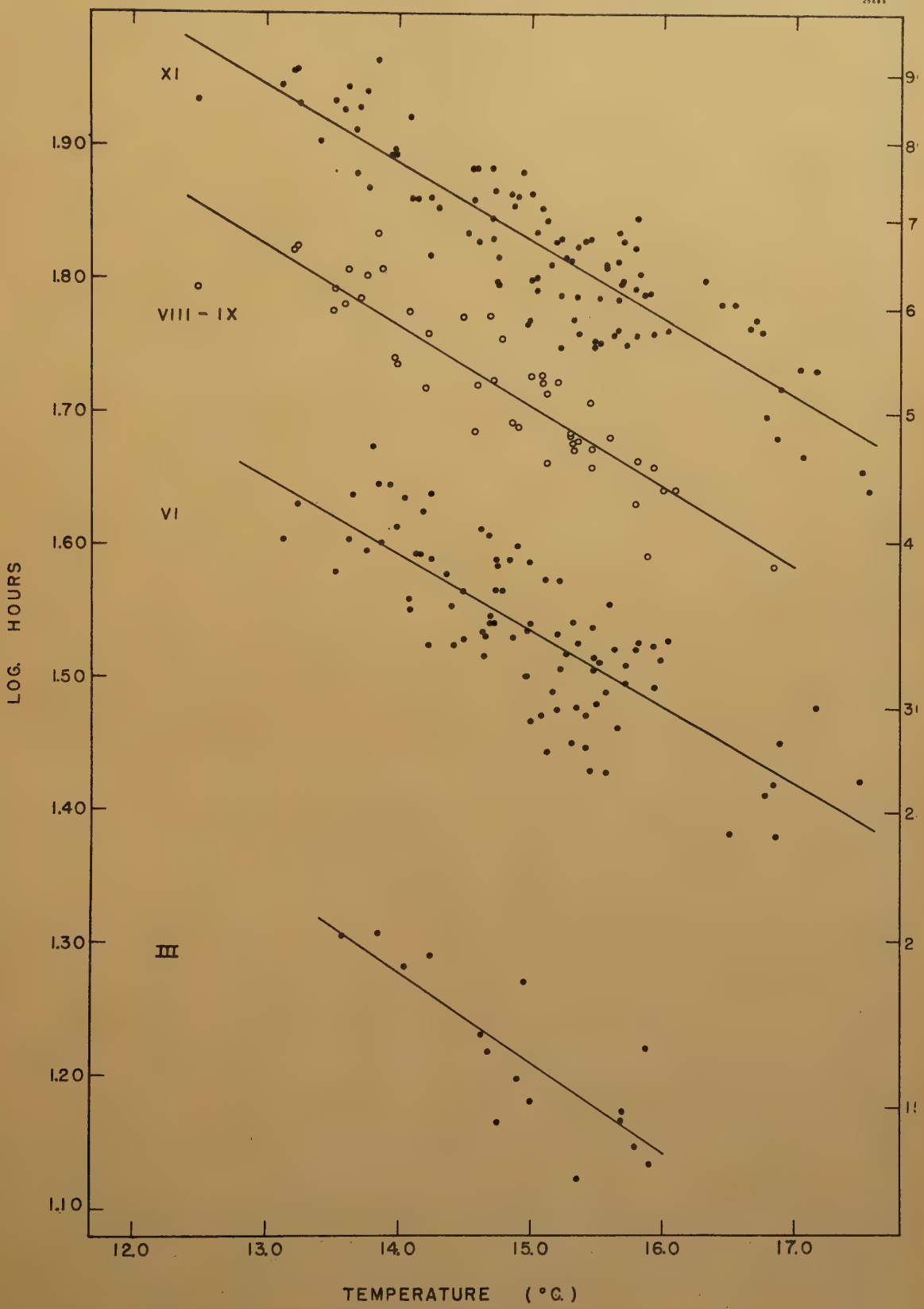


FIGURE 1. - REGRESSION DIAGRAM SHOWING THE INFLUENCE OF TEMPERATURE (°C) ON THE TIME OF DEVELOPMENT (LOG. HOURS) OF PILCHARD EGGS TO FOUR SELECTED STAGES OF DEVELOPMENT.

Table 3.-Regression data for figure 1. (X = temp.° C and Y = log. time, in hours, in the formula: $Y = a + b X$)

	Stage III	Stage VI	Stage VIII-IX	Stage XI	Four lines fitted simultaneously
No. items	16	86	46	100	
$\overline{X}$	14.92900	15.00900	14.73700	15.11610	
$\overline{Y}$	1.21278	1.53437	1.72081	1.82242	
a	2.22101	2.39977	2.61754	2.70825	
b	-0.06753	-0.05766	-0.06085	- .05860	-0.05897
Dev.est.[1/]	.03720	.03910	.02700	.03180	

[1/] Standard error of estimate

Table 4.--Time (in hours and minutes after spawning) required to reach a stage of development at different temperatures

Temperature	Stage III	Stage VI	Stage VIII - IX	Stage XI
17.0°C	-	26:17	-	51:31
16.5°C	-	28:05	41:04	55:07
16.0°C	13:49	30:01	44:03	58:58
15.5°C	14:56	32:04	47:14	63:05
15.0°C	16:09	34:16	50:40	67:29
14.5°C	17:27	36:37	54:21	72:12
14.0°C	18:52	39:08	58:18	77:14
13.5°C	20:23	41:50	62:31	82:38

lines in figure 1. First in importance is the time duration of a stage of development which occupies several hours, whereas a sample may be collected during any part of the stage. Consequently, the estimate of age of any given specimen would err, on the average, by a quarter of the time occupied by the stage in the egg's development - a matter of three hours at most. Second, there is the period of time over which spawning is spread (chiefly 8:00 p.m. to midnight), which is represented in our calculations by the midpoint of this time (10:00 p.m.). This might result in an error of as much as two hours in a few instances. Third, not all eggs develop at the same rate even under identical conditions, although the variability resulting from this cause is probably slight. Fourth, there is a possibility of an error in the day of spawning to which a stage is referred; however, an error involving twenty-four hours time should result in a more marked discrepancy than any that have been observed. The temperature data used would also contribute to the variability in so far as it differed from the actual temperature under which the majority of eggs were developing at a station. This could result (1) From the concentration of eggs occurring outside the 10- to 20-meter zone in waters of different temperatures than those occurring in this stratum, and (2) from the temperature data not reflecting the mean temperature for the period of development, as would result if the temperature of the water changed materially during the period from such causes as the stirring action of strong winds[6] or upwelling.

However, the variability was not sufficient to destroy either the correlation or the consistency in slope of the regression for the four stages.

Since the Arrenhius equation has been used by previous investigators studying development of fish eggs under constant temperature conditions, it is of some interest to analyze the present data using this formula for the sake of comparison. In doing this the logarithm of rate of development (log 1/t) is plotted against the reciprocal of the absolute temperature (1/T° abs.). When this is done for each record of each of the four stages of development previously analyzed, and a line fitted to the scatter of points for each stage by the method of least squares, as is shown in figure 2, the four fitted lines are, of course, still nearly parallel, and are closely comparable to the lines derived in figure 1.[7]

6/ The temperature would be lowered if deeper, colder water was mixed with the upper layers through wind action; contrariwise, the temperature could be raised somewhat by a mixing of warmer surface water with the waters of the 10-20 m. stratum by wind action that left depths below this undisturbed.

7/ Both methods are included in the paper since, for our purposes, the correlation shown in figure 1 is more usable, while the Arrenhius formulation is needed for comparison of the pilchard with other fishes. The Arrenhius method uses the reciprocals of the values employed in the first method with the exception that the temperature is expressed as absolute temperature.

To compare the effect of temperature on pilchard development with that of development of other fishes, the temperature characteristic (Mu), also known as the thermal increment, has been calculated for each of the four stages of eggs and given in table 5. Since the temperature characteristic depends primarily on the slope of the lines, and since the four fitted lines, although nearly parallel, are not exactly so, each stage has a somewhat different Mu value. These vary from 25,800 (the value furthest out of line) to 22,100. Since the individual slopes are not significantly different from the common slope (four lines fitted simultaneously) the latter may be taken for computing the average temperature characteristic for the whole period of development, which is 22,500. This is of similar magnitude to the few Mu values that have been determined for the development of eggs of other teleosts, which range between 16,700 and 24,900. Hence the pilchard is not atypical, and the observational evidence here used gives substantially the same conclusions as the more commonly used experimental evidence.

SUMMARY

1. The rate of development of pilchard eggs as influenced by the temperature of the water was studied from samples and data collected in nature during the 1940 and 1941 surveys of pilchard spawning off southern California.

2. Evidence based on the time of occurrence of newly-spawned precleavage eggs in the samples indicates that pilchard spawning is largely limited to the four-hour period between 8:00 p.m. and midnight.

3. Experiments conducted on the vessel at sea showed that the pilchard egg ordinarily required about three days to develop to hatching.

4. It is usually possible to separate the eggs according to the several days of spawning represented in the samples; and to determine the probable length of time each stage had been developing.

5. The temperature range over which pilchard eggs were found developing in nature was from 12.5°C. to 17.6°C. However, the majority of pilchard eggs were taken at temperatures between 13.5° C. and 16.0° C.

6. The correlation of temperature with the rate of development of pilchard eggs was analyzed for four stages of eggs. Similar results were obtained for all.

7. There is no evidence that the relation between temperature and rate of development changes during incubation.

8. The time required to reach a stage of development increases about 7.15 percent for each 0.5° C. decrease in temperature.

9. The temperature characteristic (Mu) for the pilchard egg during development is about 22,500. This is of similar magnitude to the few Mu values determined for the development of other fishes.

FIGURE 2

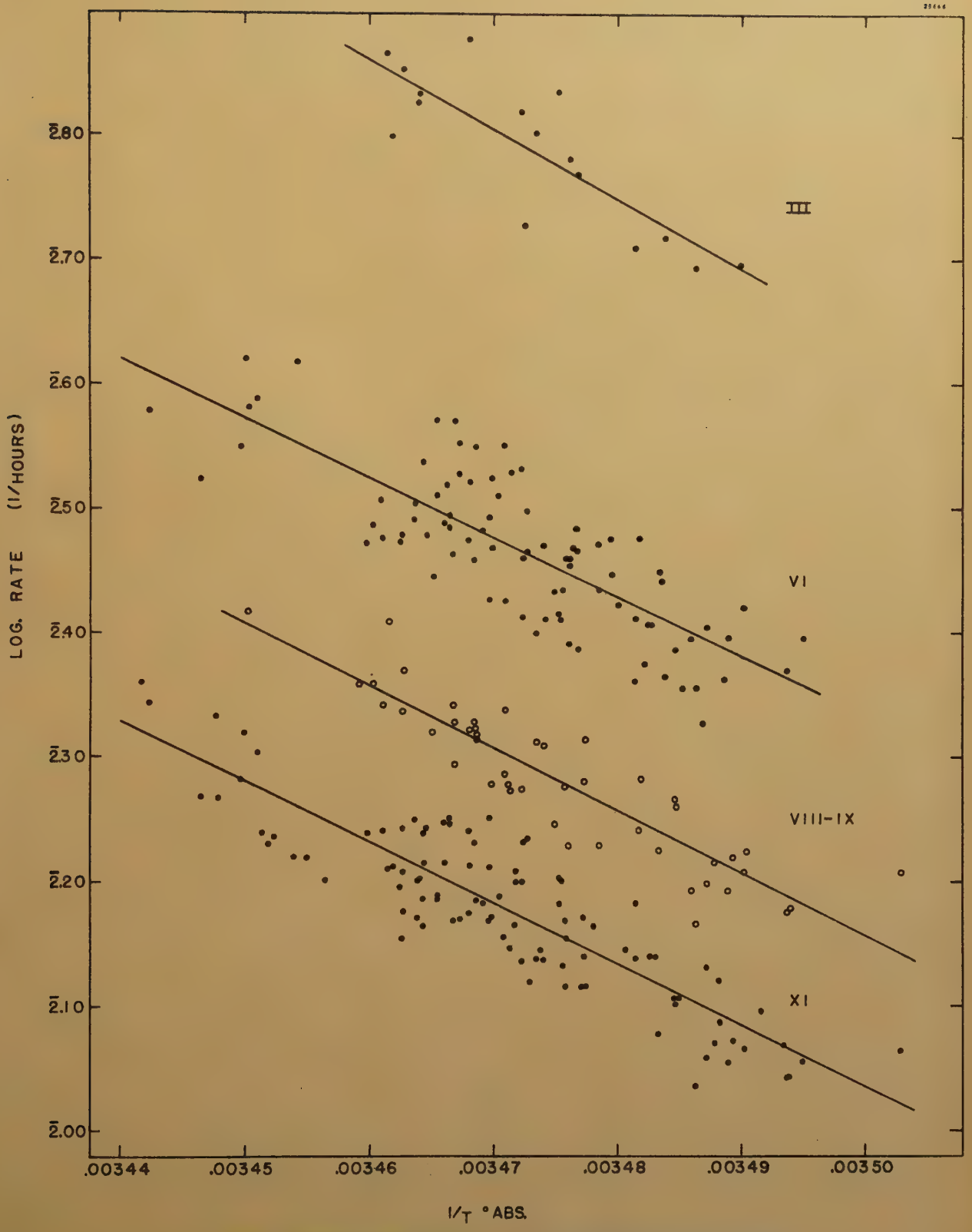


FIGURE 2. - REGRESSION DIAGRAM SHOWING THE INFLUENCE OF TEMPERATURE ($1/T^{o}$abs.) ON THE RATE OF DEVELOPMENT (LOG.1/HOURS) OF PILCHARD EGGS TO FOUR SELECTED STAGES OF DEVELOPMENT.

Table 5,-Regression data for figure 2. (X = 1/abs.temp. and Y = 1/log. time, in hours, in the formula: $Y = a + bX$)

	Stage III	Stage VI	Stage VIII-IX	Stage XI	Four lines fitted simultaneously
No. items	16	86	46	100	
$\overline{X}$	.00347309	.00347215	.00347544	.00347086	
$\overline{Y}$	8.78722-10	8.46564-10	8.27921-10	8.17758-10	
a	18.25633	15.11103	15.76771	15.12759	
b	-5605.7	-4794.0	-5032.0	-4883.5	
Dev. est.[1/]	0.0380	0.0390	0.0271	0.0290	
Mu	25,800	22,100	23,000	22,500	22,500

1/ Standard error of estimate.

APPENDIX

The development of the pilchard egg was separated into eleven stages during the investigation of pilchard spawning, a brief description of each of which follows:

Stage I

In stage I were included all pilchard eggs that were not undergoing development, either because they were so recently fertilized that cleavage had not yet begun or because they were unfertilized. Pre-cleavage eggs are usually smaller in size than are pilchard eggs undergoing development; the difference is not in the yolk mass, which is fully as large in the pre-cleavage eggs, but in the width of the perivitelline space, which may be nearly wanting. Many eggs in this stage have an accumulation of protoplasm at the animal pole to form a blastodisc.

Stage II

The period of development of the blastodermal cap is covered in stage II. Although this stage includes the early cleavage divisions, no pilchard eggs have been observed in our samples with fewer than about 128 cells. The lack of material showing early cleavage divisions is hard to explain, especially since stage I eggs were taken previous to initiating cleavage. Such divisions must take place very rapidly, indeed. While the individual cells are fairly large and quite evident, the blastodermal cap has a rugged, berry-like appearance. As the cells become minute and indistinct through repeated divisions, the cap assumes the shape of a smooth, rounded, lenticular dome. The pilchard egg floats with the blastodermal cap downwards. At the opposite end of the yolk mass is the single, large oil globule. This stage persists until segmentation cavity is formed.

Stage III

Stage III covers the period of development from the first appearance of the segmentation cavity to the definite establishment of the embryonic shield. The segmentation cavity is formed when the blastodermal cap separates from the underlying periblast in the middle portion of the cap; the cavity forms somewhat eccentrically, leaving the blastoderm on one side of the cavity somewhat thicker than elsewhere. The thickened area is the region of the developing embryonic sheild. However, the outline of the embryo is not definitely defined in this area until after this stage. The germ ring begins the envelopment of the yolk with a cellular sheath; by the end of the stage the ring has enclosed a third of the yolk mass.

Stage IV

This stage begins when the general outline of the embryo can be discerned along the median line of the embryonic shield. The germ ring at the beginning of the stage encloses a third of the yolk mass; the end-point

of the stage is arbitrarily fixed at the period of development when the germ ring encloses four-fifths of the yolk. By the end of the stage the embryo extends about two-fifths of the way around the yolk, with the cephalic region both thicker and wider than the remainder of the embryo.

Stage V

The period of development covered by this stage occupies the final enveloping of the yolk by the germ ring and the closure of the blastopore. The germ ring continues its centripetal growth until the yolk is completely encompassed by a cellular sheath; the final closure occurs just back of the posterior pole of the embryo. While the germ ring is completing this closure, there is a thickening all along the embryo, although the resulting dorsal ridge is still most pronounced in the cephalic region and tapers off posteriorward, so that even by the end of this stage the tail is hardly differentiated from the surrounding tissues, and the embryo itself is a simple, undifferentiated ridge in which somites are not yet defined. Eggs are considered as belonging to this stage until the optic vesicles are distinguishable in the head of the developing embryo.

Stage VI

This stage begins after the closure of the blastopore when the outline of the optic vesicles can be seen in the cephalic region of the embryo; it ends when the tail starts to separate from the yolk. The optic vesicles occupy fully half of the head during this stage; the somites take shape, being evident all along the embryo except in the immediate vicinity of the head and tail; the embryo extends about two thirds of the way around the yolk; the single oil globule in the yolk is a little beyond the posterior end of the embryo and retains this position in the yolk mass subsequently. This stage is of longer duration than any of the preceding three. By the end of the stage, the pupils can be discerned in the eyes, the embryo is about of equal thickness along its entire length, while the tail is somewhat swollen at its tip.

Stage VII

This stage commences when the tail begins to separate from the yolk mass; it covers the early growth of the tail until the free portion is about of equal length to the head of the embryo. Although the demarcation of the beginning of this stage is rather definite, its termination is somewhat arbitrary. All the remaining stages are separated primarily on the degree of development of the tail, as it offers the best landmarks on which to base separation into stages. During Stage VII the tail remains of uniform thickness along its length; the posterior end is rounded and even appears somewhat swollen in some individuals; the fin fold is barely discernible, extending around the free portion of the tail and along the dorsal side of the body to near the region of the head; there is either no differentiation of somites in the free portion of the tail or at best a few somites are formed at the base of the tail by the end of the stage; along the rest of the body the somites stand out sharply when viewed from above. By the end of this stage in most specimens the free tail extends up to, but not beyond, the position of the oil globule.

Stage VIII

At the beginning of this stage the developing tail is free from the yolk mass for a length greater than the length of the head; by the end of the stage about one-third of the body at the tail end is separated from the yolk. The fin-fold is becoming conspicuous, although it is barely half as wide as the embryo by the end of the stage. The intestine can be seen as a line along the ventral side of the developing tail, and the position of the vent is indicated in the fin-fold. Somites are formed along the tail, at least as far as the end of the intestine. The tail tapers posteriorly, but the tip is still rounded.

Stage IX

Approximately one-third of the body is free from the yolk at the beginning of the stage and the tail is often bent to one side; by the end of the stage the tail is always curved, either to the right or left of the yolk, and comprises about two-fifths of the total length of the embryo. The fin-fold is about half as wide as the body at the beginning of this stage, it is somewhat broader along the free ventral portion of the body than along the dorsal side; by the end of the stage the ventral fin-fold is nearly as wide as the body proper. During stage IX pigment spots (melanophores) may appear on the dorsum in two parallel rows, one on either side of the notochord, with the spots more numerous immediately behind the head; on some specimens pigmentation does not appear until after this stage. The embryo conforms less to the shape of the yolk than previously and is beginning to straighten in its middle portion; at the end of this stage the tail is curved to one side of the yolk at about a 45° angle to the plane of the embryo.

Stage X

The free tail comprises at least two fifths of the length of the body at the beginning of the stage and is as long as the remainder of the body by the end of the stage. During stage X a fundamental change in the orientation of the embryo is completed, a change begun in the previous stage. This is accomplished by the straightening of the body of the embryo and the upward flexing of the tail. The embryo as a whole is no longer curved around the yolk; rather the plane of orientation has been rotated a complete 90°. Only the head end remains curved around the yolk, the remainder of the body being straightened out into one plane, although it is U-shaped due to the flexing of the end of the tail. During this stage the tail increases in length, until its tip is nearly as far forward as the base of the head; the fin-fold is about as wide as the body along the dorsal side and somewhat wider along the ventral margin.

Stage XI

This is the last stage before hatching. At the beginning of the stage the tail stretches as far forward as the base of the head, and the posterior portion of the body free from the yolk sac is longer than the portion carrying the yolk sac, and this disparity increases during the stage.

The yolk mass is now oval-shaped; the fin-fold is wide, being 1 1/2 to 2 times as wide as the body; the tail is divided into somites to its very tip, which is now somewhat pointed. The eyes are still colorless, pigmentation taking place after hatching. This stage ends with the hatching of the egg.

KEY to Plates

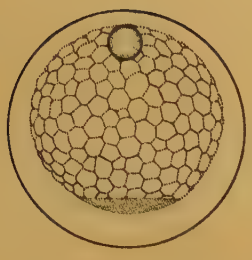
Plate 1

Fig. 1 - Stage I
" 2 - Stage II, fairly early
" 3 - Stage II, late
" 4 - Stage III, intermediate, dorsal view
" 5 - Stage IV, beginning
" 6 - Stage V, beginning
" 7 - Stage V, immediately before closing of blastopore, ventral view
" 8 - Stage VI, early
" 9 - Stage VI, late

Plate 2

Fig.10 - Stage VII, early
" 11 - Stage VII, late
" 12 - Stage VIII, late
" 13 - Stage IX, late
" 14 - Stage X, early, dorsal view
" 15 - Stage X, early
" 16 - Stage XI, early
" 17 - Stage XI, intermediate, dorsal view
" 18 - Stage XI, late

PLATE I



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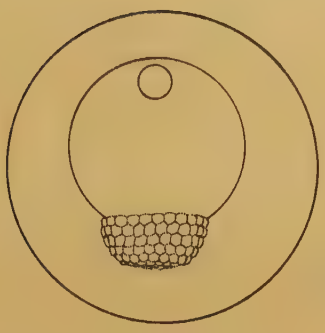

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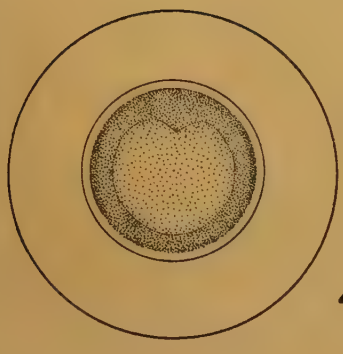

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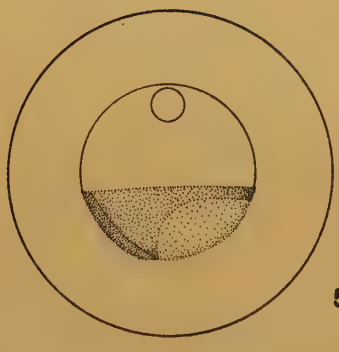

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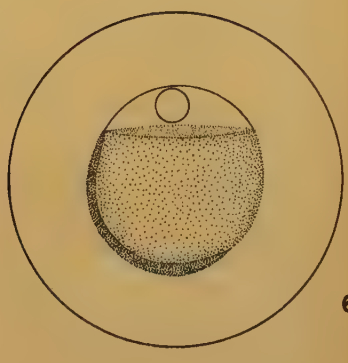

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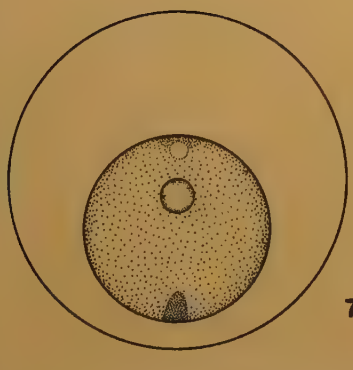

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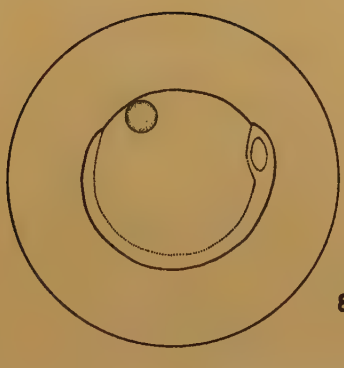

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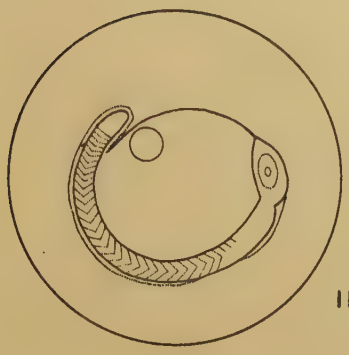
PLATE 2

10



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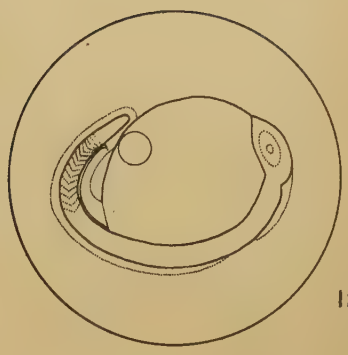

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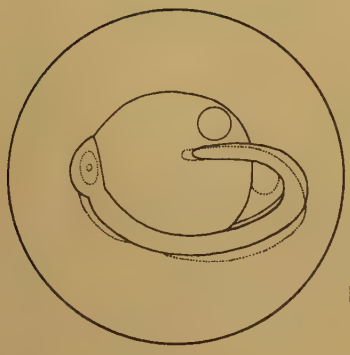

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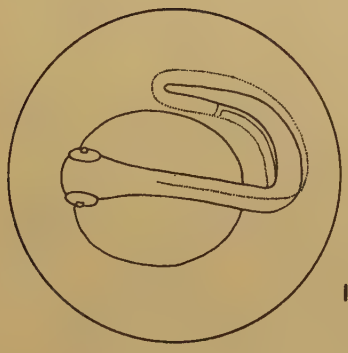

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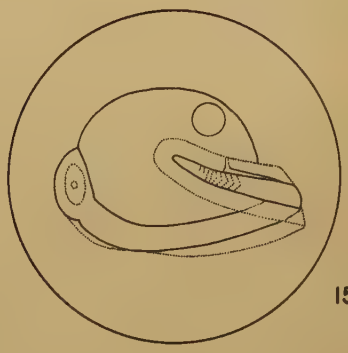

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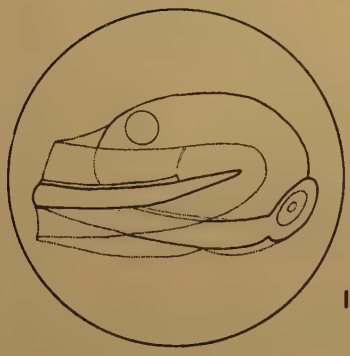

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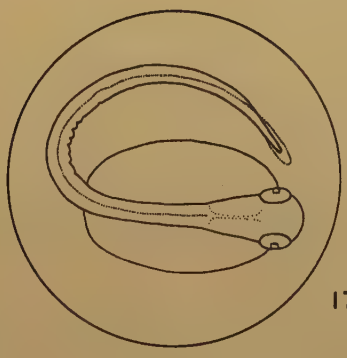

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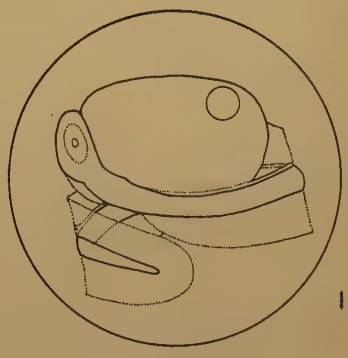

18

Table 6.-Stages of pilchard eggs in sorted portions of spawning survey samples

Station	Time preserved	Temp.	STAGE OF DEVELOPMENT										
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
101	4:20	13.95		1		1			10	12			*4
102	9:45	14.40		9				*4			4	7	
103	14:10	13.62		2				*15			*15		*11
104	18:30	13.92				24		56	20	1	2	226	202
105	22:45	14.24	6			11	56	1	140	1			*28
108	6:15	13.40							2	4			*2
109	2:30	14.59					2			*300	*22		*17
110	18:00	15.63					6						1
111	1:55	13.68					7						*11
112	22:30	14.10	15			25	32	7	243		1	28	*385
113	18:30	13.98			3	546		59	54	1	3	92	38
114	11:15	15.35	2	7	*1072	13	1	19	40				*6
115	7:30	15.36		6				*19				4	*18
117	13:00	15.89				5			1	*15		2	
118	15:00	14.62			*74	2		*170	28			5	8
119	11:00	15.66		7	10			5	7				*4
120	20:55	15.32									*14		
121	16:40	15.79				1	5		1	*12	*2		*6
122	8:20	14.97		58				*57	2		1		*5
123	19:50	15.46				3				*2			
124	15:40	14.75	1		4	40		2	20				*24
125	11:30	15.11						*10	1			8	1
126	6:30	15.52						*7				2	*16
127	2:00	15.42						*6			14	12	
128	6:00	15.48	1	6				*3					*7
129	1:40	15.33					1	2				2	
130	23:55	14.25				3	16	2	3			3	3
131	7:40	16.04		21				*53				1	*28
132	11:35	15.90	1		*36				67				*13
133	18:20	15.47								1			
134	18:15	15.44				25	48	7	52	114	3	15	40
135	12:00	15.79			*17				16				*3

*Stages marked by an asterisk were used in the correlations discussed in the body of the paper. Separation into days is indicated as follows: Stages that have been developing one to two days or three to

Table 6. - Continued

Station	Time preserved	Temp.	Stage of Development										
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
136	17:45	16.00					5			*8	*1		
137	22:50	-											3
138	3:35	15.08					1	*22			*72	1	
139	8:30	15.47		82	2			*78			2	16	40
140	12:55	15.69		1	*45	6			70				*15
201	17:25	13.65					3	*257	58		31	75	117
202	9:10	14.69		7				*34		*13	*2	52	16
203	17:10	14.04		2	*90	6	1	*56		1	3	15	
204	22:50	14.90					19			*8			*7
205	3:20	15.00						*2			*9		
206	7:50	15.09						1			1	1	
208	4:25	13.80					3		2		1		1
209	12:20	15.28						2	3				
210	4:45	15.57		1				*4				6	3
211	23:40	13.88					1		7			2	4
212	16:10	14.18		4	26	10		*215	2	1	24	12	
217	22:30	15.30				1	13			*18	*13		
219	21:00	15.46					2			*5	*3		
220	6:40	15.48		9				*8					*2
221	2:10	15.31		74				*58			7	33	1
222	17:40	14.38				21	15		13				
223	11:45	14.36		1				*110			10	22	2
224	17:25	14.60						3	1			1	*6
225	23:30	15.40									1		
228	16:10	15.51				1			2				1
229	11:20	15.29		1				8	6				
230	14:30	14.68			*4			*145	1			61	36

*(Cont'd.)

four days are underlined, while stages spawned within twenty-four hours of collection or two to three days prior to collection are not underlined. When only one group of stages is underlined at a station, the age is between one to two days, except at stations 108, 323, and 612 (three to four days). A spawning day commences at 22:00 o'clock.

Table 6. - Continued

Station	Time preserved	Temp.	Stage of Development										
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
231	22:20	14.74					4		3				
232	4:45	15.31											
234	10:50	14.73		188				*11			20	1051	135
235	0:50	15.66					1	1			11	22	
236	5:40	14.96		46				*29		1	11	4	
237	11:30	15.22		115				*33				1	*80
238	15:35	15.26			1	157		14	9				*29
239	20:00	15.12				2	98		6	*31			*28
240	1:00	15.82		3			87				1	57	3
301	4:15	13.71											2
302	18:10	13.54			*5				1				
303	23:35	12.95								1	3		
304	4:40	13.26											1
305	9:40	13.50		16			38	5		*4			
306	13:45	14.90			*13	1		*3				7	2
307	17:55	14.64				20	2	1	49			48	30
308	14:10	13.87		20	9		3	*15		*3	*8	2	4
309	15:05	13.98		7	2			*4		1	6	2	
310	6:30	14.60		10			19	20			9	5	1
311	9:50	14.43		180			19	39	29	41	43	15	3
314	9:05	14.48						1			*9		
315	4:40	14.76						1			1	2	
316	23:00	15.49											
317	23:10	15.00				4	52	5	37	18			*3
319	23:55	14.66		1			1				1		
320	9:55	15.60		3				2				3	4
321	4:45	15.16		59				*187	1		6	16	5
323	13:25	13.25		1					22	16	4	3	*19
326	21:55	15.60					1				*9		
327	16:15	15.74				11			2	1			1
328	18:55	15.46							6	15	1		
329	13:40	15.82				48			1				*3
330	13:15	14.14	2	81	10		2	*115			43	78	1

Table 6. - Continued

Station	Time preserved	Temp.	Stage of Development										
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
331	19:25	14.38			1	1		6	7		15	114	45
332	3:35	15.42		5				*4	1			31	
333	9:20	15.46		6	2			1				2	3
334	15:15	14.38			1							14	2
335	23:15	15.49					1						
336	4:15	15.50	1	25				*48		1		23	9
337	9:50	14.58											
338	17:00	14.78							1				1
340	7:10	15.80		7				*5					*5
401	3:00	15.68											1
402	17:20	14.18		1	5	2		13	26	21	2	11	7
403	23:40	12.68											1
404	5:00	13.97		17			9		4	*25			*9
405	10:40	13.59	1	7			18			*35			*14
406	14:15	13.12		1				*2			1		*2
407	18:15	13.84			*5			*11			*2		*6
408	13:15	13.80						31	11			2	2
409	13:25	13.76	1	81	1			*146			*58	1	*9
410	18:35	16.20											
411	8:40	14.70	1	7				*36			19	8	1
412	22:30	13.84				31		8	2			2	2
413	17:30	14.24			871	23		*540	16	2	18	476	87
414	8:40	14.69	1	147		1	14	*281		37	142	93	30
415	4:25	13.98		2			262		43	*208	*4		*28
416	23:10	14.85				2	359			*305	2	1	*25
417	13:30	15.49											
418	18:10	13.93			3	7		*26				10	3
419	12:40	15.52					1						
420	22:00	16.02											
421	17:20	15.84											
422	7:45	13.68		10			4		2	1			*8
423	2:45	15.20								*1	*4		2
424	22:30	14.57					8		4	*63		4	*16
425	12:35	14.99		1				*8					1

Table 6. - Continued

Station	Time preserved	Temp.	Stage of Development										
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
426	7:10	16.03											
427	12:40	16.06											
428	7:30	15.52											
429	2:40	16.31											1
430	13:10	14.14		1				*63			16	11	6
431	19:30	15.93				1				*91	*72		
432	1:15	16.07					9	5					
433	7:25	15.84											
434	8:10	14.63		1				*3					
435	23:30	15.48										1	27
436	4:00	15.35		5				*17		1	1	6	2
437	9:00	15.62											
438	13:35	14.80		1								1	
439	17:45	14.71				1			10		1	6	*70
440	0:00	15.58					15	9			12	13	
501	5:05	15.94						*5					
502	20:20	13.03											
503	2:20	13.06								2	3		
504	7:25	14.22		2			13	*63		*11	*37		
505	12:10	12.48					7	4	4	*39	*6	5	*139
506	16:40	13.23		7			5	*324		*637	*22	2	*247
507	21:10	13.80				3	1	*7				9	4
508	15:25	13.90							1			1	
509	15:40	14.24			1		1	198	133		6	9	*70
510	12:15	15.30		1									
511	11:00	13.71		3				19	37		*2		*4
512	2:45	15.09					5	1			*20	2	
513	20:10	14.70				5	5		2	2			*2
514	12:00	13.52		237			16	*273	1	*128	*70	1	*15
515	7:45	14.49		5				*10			7	3	1
516	2:30	14.56		6		1	87	1	14	44			*76
517	4:35	14.57						1					
518	7:25	15.93		12				*39	3			1	*71
519	5:30	15.09											
520	14:50	18.48											1

Table 6. - Continued

Station	Time preserved	Temp.	Stage of Development									
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
521	9:10	16.01											
522	23:20	13.73				3	10	7	16	6	7		1
523	13:10	15.04		3				5	8				*24
524	17:50	16.09				2			1	*4			
525	23:00	16.23											
526	4:00	16.29											
527	9:10	16.48		32	5			1					
528	23:55	15:39											
529	18:55	16.72											
530	16:40	14:98		10	*32	4		1	8	3			1
531	2:40	15.95										2	1
532	20:10	16.21									1		
533	15:10	16:30											
534	10:50	14.78		248			1	*84			1		
535	22:40	15.43											
536	4:25	16.23											
537	9:35	15.17		8				2	24				1
538	14:50	15.57							2	2			*3
539	20:40	14.68				16	144		21	72	3		
540	3:10	14:94					19						
541	11:50	15.67											4
542	7:25	16:28											
601	23:45	14.52											
602	14:35	13.09											
603	20:00	13.42											
604	2:10	14:20					47	2	1	*4	*22		1
605	7:25	15.92											
606	12:45	14.90			1			7	2			1	
607	17:20	13.54											
608	9:40	15.27											
610	14:05	13.75											1
611	5:00	14.14											
612	16:35	13.22								*7	*1		*5
613	12:40	15.68			*19	5			2				*9
614	7:45	15.66		5					2				*3
615	3:35	15.12									5	26	

Table 6. - Continued

Station	Time preserved	Temp.	Stage of Development										
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
616	22:30	15.02											
617	3:25	16.18											1
619	5:10	15.68											
620	13:15	16.89											
621	8:40	16.82		19				2	10				
622	13:50	14.09		1									
623	19:45	14.86											
624	00:30	16.30											
625	6:10	16.66											
626	10:50	16.52											
627	16:00	17.11											
628	23:50	16.58											
629	18:10	15.60											
630	20:25	16.58						1					
631	12:50	16.44							1	2			
632	3:05	15.98											
633	22:10	16.58											
634	11:20	16.02											
635	22:10	15.60											
636	3:45	15.88											
637	9:30	15.72		3								1	1
638	14:50	15.38											
639	20:50	16.25								1			
640	2:25	13.42											
642	7:30	16.28											
1711	18:15	15.86				5	22		10	3			
1712	22:20	15.30			1		39	18	5	*5	*46	7	2
1713	3:40	14.76		24			5	1	1				
1714	6:55	15.26	1	282				*154		2	10	34	11
1715	11:00	15.52	1	7	2			39	44			1	*127
1716	15:55	15.30				36			53			1	*56
1717	21:30	15.32				82			11	*90	*45		

Table 6. - Continued

Station	Time preserved	Temp.	Stage of Development										
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
1721	14:35	15.87			*3				15	1			1
1722	10:15	16.44		59	1			25	230			1	*10
1723	6:05	15.22		11				*58				9	*86
1724	1:55	15.50				1	713	102	4	14	122	195	58
1725	21:40	15.35				1	28			*6	*12		1
1726	17:30	15.41	1			12			4				*2
1727	13:10	15.00		1	*5		1	7	3		1		*6
1728	8:40	14.99		41			1	*332				39	*176
1730	17:50	16.22					1			161	412	152	
1731	22:05	16.51	79	1			56	457			1	32	43
1732	3:00	17.15		1			2	2	1				
1733	10:20	16.54		38	50			12	53		1		*4
1734	6:15	15.72		28				*58	2			3	*46
1735	1:45	15:12		9			8	*122	4	*89	*79	1	
1736	21:25	15.08				35	842		667	76			*11
1737	17:45	15.22				44			1136			1	*103
1740	17:40	17.56					1	4					*4
1741	16:05	16.92				1	436			2	69	193	
1742	12:20	16.85	1	1	16	28	1		7	*53	*19		
1743	8:00	16.66	4	633	1		1	42	146	1			*14
1744	20:25	16.62	18			1	43	150			3	31	84
1745	1:15	15.78		1		1	1038	3062		1	7	77	81
1746	7:10	15.63		38				*22					*27
1747	11:20	15.86		2	4			20	279				*135
1751	22:00	16.86	1				1	*33					*20
1752	20:45	17.06	4			1	10	30	1	1	4	5	*75
1753	2:10	16.89		21				*175				5	*306
1754	7:35	15.82		420				*252	1			5	15
1755	12:55	16.32		1	10	90		3	26	12			*14
1760	17:35	17.02				1	8					1	
1761	4:00	17.16		38		1		*97	13			1	*57
1762	8:50	16.70		56	14			9	41				*5
1763	13:45	16.72			3	4	1		12	11			
1764	20:00	16.62			1		26		1	2	15	7	

Table 6. - Continued

Station	Time preserved	Temp.	Stage of Development										
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
1911	7:30	14.08											
1912	11:15	13.83		4					2		1	1	
1913	15:55	13.90											
1914	21:40	14.19				9	15	1	3				
1915	2:55	14.71	1	12			14	14		*13	*10		
1916	8:00	14.65		1			1	*9			4	15	2
1917	12:50	14.74		7	1			*32				8	*128
1920	12:50	14.84		6				2			1	7	26
1921	21:50	15.64											
1922	17:50	15.23						2					
1923	14:05	14.48		5			5	105	87	48	75	127	72
1924	9:35	14.08		3			13	145	24	*140	*39		*2
1925	7:25	14.41		71			38	*270	86	225	71	26	17
1926	2:35	14.70	1	9			32	18	29	43	9		*7
1927	21:30	14.87		1		1	18		55	5			*28
1928	16:45	15.35				1			15				*13
1930	1:05	13.80											
1931	11:35	16.47											
1932	20:40	15.70					1						
1933	3:00	15.66						*2					
1934	8:05	15.20		1			1	*47		5	25	26	140
1935	12:45	14.24		31				*127	1	2	47	95	10
1936	18:30	14.52				149		40	380				*329
1937	00:55	15.45				1	5	*25	1	*6	*27	4	
1940	6:25	15.24											
1941	9:25	16.61			1								
1942	6:10	16.60		2				1					1
1943	22:25	16.49											
1944	18:25	15.66						1	18				*9
1945	14:45	15.00		5				4	3	1	1	19	49
1946	10:40	14.48	1					*1953	1	4	34	32	8
1947	7:55	14.86		8				*46		1	45	139	6
1951	00:10	16.84						*2			1	9	4
1952	23:45	16.78	1				4	*58				3	*19
1953	19:25	16.80				5	169	3		3	5	36	18

Table 6. - Continued

Station	Time preserved	Temp.	Stage of Development										
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
1954	14:15	15.80		2					6				
1955	8:45	15.32	1	97				*72	1		1	15	*118
1960	19:20	14.83											
1961	5:20	16.66											2
1962	10:35	16.24		1					1				
1963	15:05	15.66							2				*2
1964	20:10	15.80				1	3		10	*55	*1		*2
2111	2:30	15.62											
2112	7:50	15.58							1				1
2113	12:35	15.33	7	186	70		2	271	585		9	31	51
2114	17:45	15.45				89	164	2	201	4		1	*46
2115	23:45	14.72	4				4	3	104	73	2		*41
2116	5:15	15.72		4				*149				37	77
2117	10:00	16.22											
2120	12:55	16.88								1			
2121	21:30	16.10					1						
2122	17:30	15.76				1				1			
2123	14.15	16.60				1							
2124	7:35	16.75		303			1	34	10				*26
2125	4:05	15.73		2									1
2126	20:25	15.92											
2127	19:10	16.05											
2128	15:00	16.06											
2130	00:45	15.57		1				*10	2				
2131	5:35	17.55											
2132	9:55	17.58		2					2				
2133	13:55	15.29			1	2			2				
2134	17:25	15.70						48	93	44	4	15	*109
2135	21:30	14.30	5			20	40	48	296	5	5	16	*199
2136	2:05	14.94					11	8	121	44	5	8	*253
2137	6:35	15.99		10				*3		1			
2140	00:15	16.76											

Table 6. - Continued

Station	Time preserved	Temp.	Stage of Development										
			I	II	III	VI	V	VI	VII	VIII	IX	X	XI
2141	21:45	15.69											
2142	18:15	17.70										1	2
2143	4:00	17.04						1					1 (+2)
2144	23:55	16.90											
2145	20:20	15.97											
2146	16:10	15.70											
2147	11:50	15.04						5	12			3	*45
2151	23:20	16.65											
2152	14:20	17.56					3						19
2153	9:15	16.26											
2154	4:40	15.83											
2155	00:10	16.42											
2160	19:45	12.98		1									
2161	4:00	16.70		2				1	6				1
2162	8:30	17.06		13	34	197			3	6	23	17	
2163	12:55	16.24	1			65	13		8	13			
2164	17:45	16.58				1							
2311	20:35	15.08											
2312	1:35	14.36											
2313	7:15	13.33											
2314	12:35	14.75		25	*104			*15			1		*53
2315	21:30	16.02											
2316	5:25	16.50											
2317	12:00	16.65		1									
2321	14:15	16.80											
2322	18:20	15.04				6	5		15	1			*5
2323	14:45	15.57				9		3	8			1	*4
2324	10:45	13.76	3	9								1	
2325	7:05	14.64	1	117			5	*153		18	30	41	9
2326	2:25	14.53									2	1	
2327	21:20	16.36											
2328	16:55	16.60											
2330	8:55	15.38											
2331	1:15	16.02											
2332	6:25	14.10											
2333	11:20	15.70							1				

Table 6. - Continued

Station	Time preserved	Temp.	Stage of Development										
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
2334	15:50	15.40				5	2		3	5	2	2	2
2335	23:55	13.77				1		3	49			1	*54
2336	6:45	14.78								*1	*7	1	
2337	11:25	16.58											
2340	3:40	15.36											
2341	23:45	17.36											
2342	13:55	16.44											
2343	11:30	17.03											
2344	7:35	15.44								1		3	
2345	3:55	15.20						*11	2			3	
2346	22:25	14.14				2	1	2	8		1		*9
2347	17:15	15.19			1	4	15	1	12			1	*20
2351	21:00	15.56											1
2352	2:15	15.76							1				
2353	8:00	15.68											
2354	11:40	16.38											
2355	16:00	16.41											
2360	13:30	14.62											
2361	9:50	14.60											
2362	5:50	16.92											
2363	1:50	16.18											
2364	21:05	17.24											
2514	10:10	14.07						*2					
2515	14:45	15.15											*5
2525	19:30	15.48					13			1			
2535	3:05	15.40		2			17			1	1		

Cruise dates of collections listed in Table 6

Cruise No.	Station No.	Date
1	101-140	March 5-14, 1940
2	201-240	March 20-28, 1940
3	301-340	April 4-14, 1940
4	401-440	April 22-May 3, 1940
5	501-542	May 10-19, 1940
6	601-642	May 27-June 7, 1940
17	1711-1764	March 21-30, 1941
19	1911-1964	April 14-25, 1941
21	2111-2164	May 8-17,1941
23	2311-2364	June 2-12, 1941
25	2514-2535	June 27-30, 1941

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